We claim:

1. A method of writing a light-guiding structure in a bulk glass substrate comprising:

selecting a bulk glass substrate made from a soft silica-based material; and

focusing a pulsed laser beam at a focus within said substrate while translating the focus relative to the substrate along a scan path at a scan speed effective to induce an increase in the refractive index of the material along the scan path relative to that of the unexposed material while incurring substantially no laser-induced breakdown of the material along the scan path that would inhibit effectiveness of the scan path as a waveguide.

2. The method of claim 1 wherein said material has an annealing point lower than about 1350°K.

3. The method of claim 2 wherein the material has an annealing point lower than about 1325°K.

4. The method of claim 2 wherein the material is substantially transparent to the laser wavelength.

5. The method of claim 2 wherein the ratio of the band gap of the material to the energy of the laser irradiation is at least about 5.

6. The method of claim 2 wherein the peak intensity of said laser beam at the focus is at least about 10^{14} W/cm^2.

7. The method of claim 2 wherein the material includes a first dopant selected from the group consisting of GeO_2, B_2O_3, Al_2O_3, and P_2O_5.

8. The method of claim 7 wherein said material further includes a second dopant different in composition from said first dopant, said second dopant being selected from the group consisting of GeO_2, B_2O_3, Al_2O_3, and P_2O_5.

9. The method of claim 2 wherein the laser pulse duration is from about 18 fs to less than 120 fs.

10. The method of claim 2 wherein the laser repetition rate is from about 1 kHz to less than 200 kHz.

11. The method of claim 2 wherein the pulse energy is within the range from about 1 nJ to about 10 μJ.

12. The method of claim 11 wherein the pulse energy is within the range from about 1 μJ to about 4 μJ.

13. The method of claim 11 wherein the pulse energy is within the range from about 1 nJ to about 10 nJ.

14. The method of claim 2 wherein the scan speed is greater than 20 μm/s and less than about 500 μm/s.

15. The method of claim 2 wherein the focus is translated relative to the substrate in a scan direction that is substantially parallel to the laser beam.

16. The method of claim 2 wherein the focus is translated relative to the substrate in a scan direction that is substantially perpendicular to the laser beam.

17. The method of claim 2 wherein the focus is translated relative to the substrate in three dimensions.

18. The method of claim 2 wherein the diameter of the light-guiding structure is about 3 μm to about 4 μm.

19. The method of claim 2 wherein translation of the focus once along the scan path induces a refractive index increase of more than about 0.0001.

20. A product made by the process of claim 2.

21. The product of claim 20 wherein the product is a device selected from the group consisting of a Y-coupler, a directional coupler, a star coupler, a Mach-Zehnder device, a loop mirror, a demux coupler, an Er-doped single- or multi-stage amplifier, and devices having surface-modified thermal, piezoelectric, or trench-type activators.

22. A diffraction grating made by the process of claim 2.

23. The product of claim 22 wherein the line spacing is about 0.5 μm.

24. A method of writing a light-guiding structure in a bulk glass substrate comprising:

selecting a bulk glass substrate made from a hard doped silica-based material; and

focusing a pulsed laser beam at a focus within said substrate while translating the focus relative to the substrate along a scan path at a scan speed effective to induce an increase in the refractive index of the material along the scan path relative to that of the unexposed material while incurring substantially no laser-induced breakdown of the material along the scan path that would inhibit effectiveness of the scan path as a waveguide.

25. The method of claim 24 wherein the material is substantially transparent to the laser wavelength.

26. The method of claim 24 wherein the ratio of the band gap of the material to the energy of the laser irradiation is at least about 5.

27. The method of claim 24 wherein the peak intensity of said laser beam at the focus is at least about 10^{14} W/cm^2.

28. The method of claim 24 wherein the material includes GeO_2.

29. The method of claim 24 wherein the laser pulse duration is from about 18 fs to less than 120 fs.

30. The method of claim 24 wherein the laser repetition rate is from about 1 kHz to less than 200 kHz.

31. The method of claim 24 wherein the pulse energy is within the range from about 1 nJ to about 10 μJ.

32. The method of claim 31 wherein the pulse energy is within the range from about 1 μJ to about 4 μJ.

33. The method of claim 31 wherein the pulse energy is within the range from about 1 nJ to about 10 nJ.

34. The method of claim 24 wherein the scan speed is greater than 20 μm/s and less than about 500 μm/s.

35. The method of claim 24 wherein the focus is translated relative to the substrate in a scan direction that is substantially parallel to the laser beam.

36. The method of claim 24 wherein the focus is translated relative to the substrate in a scan direction that is substantially perpendicular to the laser beam.

37. The method of claim 24 wherein the focus is translated relative to the substrate in three dimensions.

38. The method of claim 24 wherein the diameter of the light-guiding structure is about 3 μm to about 4 μm.

39. The method of claim 24 wherein translation of the focus once along the scan path induces a refractive index increase of more than about 0.0001.

40. A product made by the process of claim 24.

41. A method of writing a light-guiding structure comprising:

selecting a bulk glass substrate including a silica-based material made by a flame hydrolysis process; and

focusing a pulsed laser beam at a focus within said substrate while translating the focus relative to the substrate along a scan path at a scan speed effective to induce an increase in the refractive index of the material along the scan path relative to that of the unexposed material while incurring substantially no laser-induced breakdown of the material along the scan path that would inhibit effectiveness of the scan path as a waveguide.

42. A method of writing a light-guiding structure in a bulk glass substrate comprising:

selecting a bulk glass substrate made from a silica-based material doped with a dopant selected from the group consisting of B_2O_3, Al_2O_3, and P_2O_5; and

focusing a pulsed laser beam at a focus within said substrate while translating the focus relative to the substrate along a scan path at a scan speed effective to induce an increase in the refractive index of the material along the scan path relative to that of the unexposed material while incurring substantially no laser-induced breakdown of the material along the scan path that would inhibit effectiveness of the scan path as a waveguide.

43. A method of making a three-dimensional internal tunnel light-guiding structure within an interior of a glass body, said method comprising:

providing a glass body, said glass body having an interior, said interior having a homogeneous composition and refractive index;

providing a pulsed laser beam;

focusing said pulsed laser beam to form a converging focused laser beam having a refractive index increasing focus; and

positioning said focus inside said glass body interior and controlling relative motion between said focus and said glass body, wherein said focus forms a raised refractive index waveguiding core structure which tunnels through said glass body, said raised refractive index waveguiding core for guiding light and cladded by said glass body.

44. A method as claimed in claim 43, said glass body having a first exterior side and a second exterior side, said first exterior side lying in a first plane, said second exterior side lying in a second plane, and said second plane being non-parallel to said first plane, wherein said waveguiding core tunnels from an input at said first exterior side to an output at said second exterior side.

45. A method as claimed in claim 43, said glass body having a planar exterior base side, wherein said waveguiding core tunnels in a plane non-parallel to said planar base side.

46. A method as claimed in claim 43, said method including forming a first raised refractive index waveguiding core tunnel path, a second raised refractive index waveguiding core tunnel path, and a third raised refractive index waveguiding core tunnel path, wherein said third tunnel path is in a plane separate from said first tunnel path and said second tunnel path.

47. A method as claimed in claim 43, said step of providing a glass body including providing a glass homogeneously doped with a glass-softening dopant.

48. A method as claimed in claim 43, wherein said focus forms a refractive index increase of at least 1 X 10^{-5}.

49. A method as claimed in claim 43, wherein said focus forms a refractive index increase of at least 1 X 10^{-4}.

50. A method as claimed in claim 43, said method including forming a first raised refractive index waveguiding core tunnel path and a second raised refractive index waveguiding core tunnel path wherein guided light is coupled from said first core tunnel path to said second core tunnel path.

51. A method as claimed in claim 43, wherein said method includes forming a wavelength division multiplexer for multiplexing a plurality of optical wavelength channels, said forming including forming a plurality of waveguiding core tunnel inputs for separately inputting the plurality of optical wavelength channels, forming a multiplexing region for multiplexing said inputted channels, and forming an output waveguiding core tunnel for outputting said multiplexed inputted channels.

52. A method of direct writing a waveguide in a silica-based material substrate comprising the steps of:

producing a pulsed laser beam having a wavelength beyond an absorption edge of the silica-based material substrate and a pulse duration less than 150 femtoseconds (fs);

focusing the laser beam to a spot within the silica-based material substrate;

adjusting pulse energy of the laser beam within a range in which an accompanying generation of heat has the effect of saturating refractive index increases associated with incremental increases in the pulse energy; and

relatively translating the beam and silica-based material along a scan path to provide for increasing refractive index along a scan path within the silica-based material while incurring substantially no laser-induced breakdown of the material along the scan path that would inhibit effectiveness of the scan path as a waveguide.

53. The method of claim 52 in which the step of focusing includes focusing the laser beam through a numerical aperture greater than 0.2.

54. The method of claim 53 in which the refractive index increase is saturated at less than 1 microjoule (μJ).

55. The method of claim 54 in which the laser beam has a wavelength of approximately 800 nanometers (nm).

56. The method of claim 55 in which the material is a fused silica and the refractive index increase is saturated at around 0.8 microjoule (μJ).

57. The method of claim 55 in which the material is a borosilicate and the refractive index increase is saturated at around 0.5 microjoule (μJ).

58. The method of claim 54 in which the step of producing includes producing the laser beam with a repetition rate that is slower than a thermal diffusion rate of the silica-based material so that each pulse heats the material independently of adjacent pulses.

59. The method of claim 58 in which the pulse duration is less than 50 femtoseconds (fs).

60. A three-dimensional waveguiding structure comprising the silica-based material substrate and a plurality of waveguides direct written into the substrate in accordance with the method of claim 52.